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Student Sleep Patterns when Exposed to Mindfulness Reminders

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Abstract

University students are plagued with increased levels of stress and anxiety which can lead to poor sleep quality and quantity. Breathing techniques have demonstrated counteractive effects to the chronic stresses that the population encounters on an everyday basis. Wearable technology, such as Apple Watches, contain a mindfulness feature that encourages its users to pause throughout the day and engage in mindfulness through resonant breathing. Wearable technology has become increasingly accessible and is also growing in accuracy to measure different biometrics such as sleep quality and quantity. The purpose of the present study was to examine if the mindfulness reminders initiated by the Apple Watch will positively correlate with better sleep quality and quantity. Participants were encouraged to participate in at least one mindfulness reminder a day, which consisted of one minute of mindful breathing, as well as sleep while wearing their Apple Watch to record sleep data on the Sleep++ application. This study suggests that the Apple Watch mindfulness reminders slightly decrease restful sleep by about 1%. It was also found that the more time the participant sleeps, the more restful sleep they will have overall. Lastly, it was suggested that exercise has a positive effect on restful sleep.

Introduction

Stress has been shown to be correlated with both inadequate quality and quantity of sleep (Weathers et al., 2020). Inadequate sleep is faced by many university students on an everyday basis. Inadequate sleep quality can lead to increased levels of depression and anxiety. The impacts of increased levels of depression and anxiety exacerbate poor sleep. There are many studies that look at 6-week controlled interventions using active mindfulness and meditation practices, but college students are not commonly included in the study populations. Many studies use self-reported surveys to test quality of sleep or the decrease in anxiety levels after a controlled intervention. Self-reported surveys are subjective and are not always consistent with the participants' objective measurements, especially when analyzing sleep quality (Weathers et al., 2020).

Wearable technology has become more accessible for analyzing different biometrics such as sleep quality or heart rate. Wrist watches, such as the Apple Watch, have a feature that encourage the user to participate in mindfulness throughout the day. The Apple Watch has a specific application called Mindfulness which alerts the user to stop and participate in one minute of mindful breathing for a set number of times per day. This study examines the effects of mindfulness practices initiated by the Apple Watch on sleep quality, also measured by the Apple Watch, in university students.

Stress

Stress is known to be a barrier to engaging in positive health behaviors (Nagy et al., 2020). Stress causes a wide variety of physiological responses that occur as a direct result of a disturbance to the body's homeostatic state. Stress systems can communicate threats throughout the entire organism and will then stimulate inflammatory mechanisms (Rohleder, 2019). When a threat is identified in the body, the acute stress response is activated and there is a chain of events that occurs with the intent of downregulating the parasympathetic nervous system while activating the sympathetic nervous system and the endocrine response (Dow, 2014). Stress-triggering situations trigger neuroendocrine responses, commonly known as the "fight or flight" response. This cortisol release, in the short term, is used to shift to a new state of homeostasis. Chronic elevation of cortisol is detrimental to health as it is associated with depression as well as decreasing the immune response and increasing adipose tissue deposits (Kinkead, 2013). There are numerous other health related issues that stem from chronically elevated cortisol levels such as hypertension and metabolic disorders which ultimately lead to a higher mortality rate. The hormones released include cortisol, adrenaline, gluco- and mineralocorticoids and androstenolone, a steroid hormone. The endocrine response involves corticotropin-releasing hormone (CRH). This hormone is released from the paraventricular nucleus of the hypothalamus which in turn activates the hypothalamic-pituitary-adrenal (HPA) axis. Prolonged exposure to stressors, and thus prolonged CRH exposure, has an immunosuppressive effect due to the cortisol release and will therefore increase the body's inflammation (Dow, 2014). The downstream pathophysiological effects due to stress systems are not completely understood as the stress response releases hormones that regulate further dependent systems with an ever-changing effect. These systems are constantly interacting with one another causing different effects on the body (Rohleder, 2019).

The stress system can activate and change aspects of dependent systems in the body, resulting in a short-term adaptation to threats, for example, an increase in blood pressure, blood glucose, heart rate, and stimulation of the inflammatory response. This inflammatory response can then increase cytokines in the blood. Inflammatory mechanisms can be protective in the short term, but chronic levels of low-grade inflammation can potentially lead to health consequences such as certain cancers or Type 2 diabetes. There have been multiple studies conducted that prove that self-rated chronic stress is indeed associated with inflammatory activity (Rohleder, 2019). The stress response starts with sympathetic nervous system activation and non-specific mobilization. The next phase is the coping/resistance phase and if the stressor to the homeostatic state is still present, the body's resources will deplete and result in exhaustion. During prolonged exposure to stress, physical resilience is affected and may lead to a permanent deviation from the body's homeostatic state, resulting in burnout (Dow, 2014). Burnout can be defined as a physiological syndrome that emerges from a prolonged response to chronic interpersonal stressors. Three of the key responses to burnout are overwhelming exhaustion, feelings of cynicism and a sense of ineffectiveness or a lack of accomplishment (Maslach & Leiter, 2016). Everyday stressors are very common in the university student population due to academic stress, and will ultimately lead to burnout. The stressors in the college environment are likely to be endured for a long period of time, resulting in the symptoms of a chronic stressor, which is a potentially dangerous consequence for students both while attending university and throughout life.

In college students, academic success is a huge contributor to stress levels. College students tend to report higher levels of stress than people of other age groups (Huberty et al., 2019). Around 75% of university students have reported elevated stress levels (Huberty et al., 2019). Academic pressures such as the innate need to be successful in a classroom, a fear of falling behind in one's coursework, a decreased motivation to study as the semester goes on, never feeling like there are enough hours in the day to accomplish everything and doubting themselves and their academic abilities all contribute to heightened stress levels in this population (Medic et al., 2017). Stress can lead to burnout, which college students cannot necessarily afford. These increased stress levels that college students face can lead to a wide variety of outcomes such as increased anxiety levels, loneliness, hopelessness, depression, headaches, poor sleep patterns and sleep disturbances (i.e. insomnia), decreased immune response, and sometimes even extremes such as suicidal thoughts or tendencies (De Fazio et al., n.d.). Elevated stress causes a negative impact on mental health, as described above, and also impacts physical health (Huberty et al., 2019). There is also a wide range of physiological outcomes on the body when dealing with increased levels of stress such as hypertension, high levels of muscle tension, and lower immune system defenses. These physiological outcomes that arise from both acute and prolonged stressors throughout a university student's life will ultimately result in the body entering the exhausted state. The body is unable to use any of its resources, as they have all been depleted (Dow, 2014). There is unfortunately a chain reaction starting with heightened stress levels leading to inadequate sleep and therefore health consequences, such as poor mental health, thus creating a snowball effect. It is imperative to create preventative interventions to counteract the debilitating effects of stress, while taking into account the psychosocial, biological and environmental risk factors (Zhu et al., 2017). Mindfulness practices have proven to be a technique in counteracting these effects in both university students and other demographics. The Apple Watch and other wearable technologies have begun promoting more healthful practices such as creating mindfulness features on devices. The duration of this study focused on the Apple Watch mindfulness feature to assess whether using this application and actively practicing mindfulness is beneficial in promoting better sleep patterns.

Sleep

There are two ways to classify sleep stages. The stages, as stated by Rechtschaffen & Kales, are awake, four stages of non-rapid eye movement (NREM 1-4), and rapid eye movement (REM). The rapid eye movement and the non-rapid eye movement stages of sleep have distinguished physiologic changes, including heart rate, brain activity, blood pressure, blood flow, muscle tone, sympathetic nervous activity, respiration, renal and endocrine function, body temperature and sexual arousal (Medic et al., 2017). Brain activity gradually decreases during non-rapid eye movement sleep (Medic et al., 2017). NREM stage 1 includes the stage of sleep where brain activity begins to slow down, and the muscles of the body begin to relax. Stage 2 of NREM consists of the body undergoing actual sleep and the eye movements halt. Stage 3 of NREM is classified as deep sleep and brain function is significantly reduced. Stage 4 of NREM is a continuation of the deep sleep activity. The last stage is REM sleep, where the eye lids are closed but the eyes are moving rapidly. REM sleep is the deepest sleep possible (Yildirim et al., 2019). The deeper sleep stages are called slow-wave sleep, classified as the most restorative type of sleep. Slow wave sleep occurs during the first one-third of the night (Medic et al., 2017). The neurons in the pons are able to constantly switch between rapid eye movement sleep and non-rapid eye movement sleep through sending outputs into the brainstem and spinal cord (Medic et al., 2017). The American Academy of Sleep Medicine has slightly modified the sleep classification system. In this classification, there are only three stages of NREM sleep. In these three stages, the lighter sleep is allocated to NREM 1 and NREM 2 stages and the deeper sleep is assigned to the slow wave stage, NREM stage 3.

Circadian rhythms control the sleep wake cycle through the daily rhythms of sleep sensitive orexin neurons, physiology, and behavior including control of metabolic activity, physical activity, and food consumption (Medic et al., 2017). The function of circadian rhythms is to match the external day and night cycle with sleep. This is done through the suprachiasmatic nucleus (SCN). The SCN takes direct input from the specialized photoreceptive neurons in the retina that function as brightness detectors (Medic et al., 2017). Once input has reached the SCN, the pineal gland is signaled which then is able to control the secretion of the neurohormone melatonin. Melatonin acts on melatonin receptors on cells throughout the body to synchronize circadian rhythms with the external environment (Medic et al., 2017). During the day, the retina is getting hit with light and therefore the SCN can suppress the pineal gland from producing melatonin. During the night, when there is not a lot of outside light hitting the retina, the SCN does not suppress the pineal gland and therefore the pineal gland is able to secrete melatonin.

Nightly melatonin and sleep both play critical roles in cell maintenance and clearance of waste metabolites from the brain (Nedergaard & Goldman, 2020).

Both sleep quantity and quality play essential roles in maintaining a healthy lifestyle. Sleep is vital to assist the brain with both cognitive function and the body's systemic physiology (Medic et al., 2017). Sleep is a crucial player in brain function and systemic physiology, which includes appetite regulation, metabolism, and functioning of the different systems of the body such as the immune, hormonal and cardiovascular systems (Medic et al., 2017).

Characteristics of normal sleep include sufficient duration, good timing and regularity of the sleep schedule, and good quality with minimal disruptions (Medic et al., 2017). Normal sleep characteristics such as sleep timing, quality, and sleep stage organization vary widely (Barclay & Gregory, 2013). As the body ages, there is a significant shift to the quality and quantity of sleep including changes in the spindle density, slow wave sleep, and sleep continuity and disruptions (Scullin & Bliwise, 2015). Due to both the short and long-term consequences of insufficient sleep in one's life, it is crucial to practice and maintain good sleep quality in order to delay the cognitive functioning impairments that are a potential risk later in life (Scullin & Bliwise, 2015). Multiple psychological tests have been conducted over a wide range of studies proving that normal sleep patterns are able to assist in stabilizing memory and aid in memory integration (Scullin & Bliwise, 2015).

Insufficient sleep is caused by a wide range of factors such as environmental factors or social pressures. Sleep disruption risk factors that come into play are a combination of psychologic, biologic, genetic, and social factors (Medic et al., 2017). In a study conducted using smartphone data, it was found that biological drives are weakened by social pressures, which delay bedtimes (Walch et al., 2006). The pace of the day increasing coupled with everyday stressors leads to days becoming longer and sleep times becoming shorter (Xu et al., 2020). University students are prone to stress and lack of sleep, exacerbated by drinking excessive amounts of caffeine. Drinking these excessive levels of caffeine in order to cope with tiredness has proven to be detrimental to overall sleep quality, thus leading to a cyclical harmful affect overall (Medic et al., 2017). Another environmental risk factor is nighttime light pollution that suppresses melatonin and disrupts the circadian sleep rhythms. An increase of nighttime light pollution, through utilizing a computer or smartphone screen on a more regular basis or studying in a well-lit area until late hours of the night, and a decreasing exposure to natural sunlight on an everyday basis, causes another injurious effect to university student's health (Medic et al., 2017).

There are many short term and long-term consequences to inadequate sleep quality and quantity. Short term consequences of different sleep disruptions include somatic pain, increased stress responsivity, reduced quality of life, emotional distress, mood disorders, and varying cognitive, memory, and performance deficits (Medic et al., 2017). The cognitive disruptions that result from inadequate sleep include a decrease in attention, executive function, memory formation, and emotional reactivity. Tasks such as decision making, risk taking behavior, and judgement all contain some level of impairment (Medic et al., 2017). Fragmentation in sleep was also concluded to reduce insulin sensitivity and glucose effectiveness, as well as increase cortisol levels (Medic et al., 2017). Long-term consequences of insufficient sleep quality and quantity include cardiovascular disease, hypertension, dyslipidemia, metabolic syndrome, Type 2 diabetes mellitus and certain cancers (Medic et al., 2017).

Sleep disorders result from stress, external factors, and genetics, but all significantly affect one's quality of daily life (Yildirim et al., 2019). There are about 100 sleep disorder classifications, but they typically are displayed in one of three ways: unable to get enough good quality (i.e. sleep deprivation), unable to obtain uninterrupted sleep (i.e. disrupted sleep), or suffering from different events that occur during sleep itself (e.g. sleep apnea) (Medic et al., 2017). Sleep disruption happens due to an increase in the activity of the sympathetic nervous system and the hypothalamic-pituitary-adrenal axis. Disruption can also result from changes in circadian rhythms, metabolic effects, or proinflammatory responses (Medic et al., 2017). Fragmented sleep has also been shown to be associated with varying levels of catecholamine, epinephrine, and norepinephrine that deviate from the body's homeostasis (Medic et al., 2017).

Inadequate sleep has demonstrated a correlation with poor mental health, a persistent problem in university students (Weathers et al., 2020). Sleep quality can affect a person's physical and mental health (Ding et al., 2020). Symptoms of anxiety, very prevalent in college students, may lead to sleep misperception or subjective reporting of sleep quality not matching objective measurements (Weathers et al., 2020). A study conducted to see the effects of insomnia on perceived anxiety along with the metabolic risks that occur. It was concluded that when college students experience insomnia symptoms, they have a greater likelihood of perceiving life events as more stressful and feeling more anxious overall (Medic et al., 2017). Studies done to compare pharmacological treatments with non-pharmacological treatments on insomnia concluded that the effects of non-pharmacological treatments are able to be better sustained over time (Kline, 2014).

It has been demonstrated that higher levels of mindfulness, a non-pharmacological approach, are correlated with better sleep quality. A study observing the association between mindfulness and sleep revealed that higher levels of dispositional mindfulness were correlated with better sleep patterns due to a person's perceived control over their own health (Imel et al., 2018). Mindfulness has been shown to improve sleep disorder symptoms and thus improve sleep quality overall (Imel et al., 2018). In a cross-sectional study, higher trait mindfulness was associated with better self-reported sleep quality as well as reduced sleepiness during the day and dysfunctional sleep beliefs (Ding et al., 2020).

Exercise Effects on Sleep Quality

Exercise is a growing field of research for a non-pharmacological approach to increase sleep quality and quantity (Kline, 2014). Through various studies, it is suggested that daytime exercise is a possible factor to enhance sleep (Youngstedt et al., 1997). Epidemiologic studies have shown that there is a positive association between self-reported exercise habits and better subjective sleep (Youngstedt & Kline, 2006). Primary care physicians, exercise scientists, numerous articles throughout scientific literature, and theories about energy conservation and sleep functionality on body restitution all suggest that exercise has a positive correlation with better sleep overall (Youngstedt et al., 1997). The scientific literature demonstrates that exercise has similar effects on good sleepers as does melatonin or hypnotic medications (Youngstedt & Kline, 2006). Exercise has also been shown to be associated with a decrease in cardiovascular mortality as well as improve overall mental health, creating more reasons for the use of exercise as an alternative to other pharmacological or sleep treatments (Youngstedt et al., 1997). Exercise has also been shown to improve overall mood state, which is a possible factor that can improve sleep quality (Uchida et al., 2012). Due to this correlation, acute and regular exercise are recommended through both sleep experts and scientific literature (Youngstedt & Kline, 2006).

When the body participates in some form of exercise, the concentration of antibodies in the blood decreases, therefore regulating inflammation levels (Cao et al., 2020). It has been shown that physical activity alters the autonomic nervous system, the endocrine system, and somatic functioning (Uchida et al., 2012). Chronic exercise is able to substantially change somatic functions, which include long-term improvements in cardiac function, basal metabolic rate, body composition, glycemic control, and immune function, as well as decreasing the risk of chronic somatic diseases (Uchida et al., 2012).

A study evaluated both singular intervals of exercise compared to long term amounts of exercise. It was demonstrated that even a single time exercising can increase short wave sleep, also referred to as deeper sleep (Uchida et al., 2012). Exercise had a significant effect on the amount of slow wave sleep that the participant had compared with the participants from the no-exercise condition (Uchida et al., 2012). It was also found that habitual exercise has the potential to increase slow wave sleep (Uchida et al., 2012). Lastly, chronic, or ongoing, exercise indicated a significant decrease in sleep onset latency, a decrease in time awake throughout the sleep period, and longer total sleep time (Uchida et al., 2012). Overall, exercise, in both the short and long-term, has displayed positive results in assisting with better sleep quality and quantity and is a promising non-pharmacological approach for sleep disorders.

Breathing Techniques

An increase in breathing is paramount in the response to stress. One often does not realize that, when stressed, breathing becomes shallower and more tensed. As a result, this breathing technique further increases the stressful response and activation of the sympathetic nervous system (Zhu et al., 2017). This deviation from the body's normal breathing pattern compromises homeostasis which can then trigger emotional, physiological and behavioral responses (Kinkead, 2013). The body compensates and tries to move back to homeostasis by activating different response mechanisms in the nervous, endocrine, and immune systems.

Hyperventilation and hypoventilation, breath suspension, and inhibited breathing all cause a deviation from the optimal breathing pattern (Gilbert, 2003). Hyperventilation is a behavioral mismatch in both rate and depth of breathing, resulting in expelling too much carbon dioxide and leading to hypocapnia, or lack of carbon dioxide in the blood. This lack of carbon dioxide has a variety of physiological, emotional, and behavioral consequences including a disruption in acid-base chemistry, electrolyte balance, blood flow, and oxygen delivery. Hypocapnia can also trigger psychological impairments such as anxiety, panic, anger, chronic pain, headaches, asthma and gastrointestinal distress.

Respiration is controlled by the autonomic nervous system. Therefore, due to anxiety, stimulation of the sympathetic nervous system will trigger responses such as an elevation in heart rate, muscle tension, and shallow, rapid breathing. Leptin is a hormone produced in the adipocytes (Bassi et al., 2016) and is regularly circulated throughout the blood and crosses the blood-brain barrier through the saturable receptor mediated transport system (Bassi et al., 2016). Leptin is then able to enter and stimulate the central nervous system to regulate different pathways whose function is to control appetite, thermogenesis, and possibly ventilatory function (Bassi et al., 2016). Breathing rhythm and pattern vary from person to person due to the coordinated activity of neurons that are grouped laterally in the brainstem (Bassi et al., 2016). Breathing is normally under autonomic control but can transition to somatic control due to actively participating in mindful breathing and breath control. When utilizing breath control and active/mindful breathing, humans are able to obtain more control over their autonomic nervous system, therefore, altering the balance of the sympathetic and parasympathetic activation (Chen et al., 2017).

Mindful breathing is defined as conscious and calm deep breathing and is an essential part of mindfulness based stress reduction (Zhu et al., 2017). Mindful breathing exercises are usually the first technique taught when learning mindfulness-based interventions. Mindful breathing is a core aspect of most traditional meditation practices. Mindfulness Based Stress Reduction (MBSR) is a prominent technique used in Eastern cultures and has been proven to decrease stress and anxiety in its participants (Zhu et al., 2017). Breathing and breath control are used in multiple practices, such as yoga, meditation, and prayer rituals (Zaccaro et al., 2018). Studies have shown that techniques that utilize controlled respiration create a beneficial result for overall health and well-being (Nuckowska et al., 2019). The goal of mindful breathing exercises is to teach the participants to bring their focus to their breath and feel the sensations that accompany this focused breathing (Eisenbeck et al., 2018). Yogic breathing has also been studied as having beneficial aspects on mental health, thus potentially decreasing anxiety and other mental health concerns (Schröter & Cramer, 2021). Mindful breathing interventions have been shown to boost emotion regulatory processes and regulate parasympathetic activity (Seppälä et al., 2014).

There have been multiple studies showing a decrease in mean arterial pressure when participating in resonant breathing. Resonant breathing, or breathing at 6 breaths per minute, has been shown to improve cardiovascular functions through better blood flow to internal organs and sensitivity of the sympathetic component of the baroreflex and ventricular elastance (Nuckowska et al., 2019). Breathing with a longer exhalation has been shown to improve physiological outcomes such as stress reduction and increased positive energy. The Apple Watch mindfulness feature, used during this study, focuses on participants breathing at 6 to 7 breaths per minute, thus, actively engaging the participants in resonant breathing.

Diaphragmatic breathing exercises for relaxation have been proven to reduce symptoms of anxiety. The technique of diaphragmatic breathing utilizes the contraction of the diaphragm muscle to produce negative pressure and move air downward, increasing space in the chest cavity and breathing efficiency, thus creating more efficient exhalation. Diaphragmic breathing has been tested and has demonstrated a stabilizing effect on the autonomic nervous system (Chen et al., 2017). Diaphragmatic breathing is able to increase carbon dioxide levels in the blood and stimulate the parasympathetic nervous system to cause relaxation, increase body temperature, and stabilize both blood pressure and heartbeat (Chen et al., 2017). It is one of the most useful techniques to reduce levels of stress and anxiety (Chen et al., 2017).

Mindfulness

Mindfulness has been recently studied as an important coping mechanism that is able to be sustained for a longer period compared to pharmacological approaches. There has been a lot of previous research that has shown that long-term mindfulness training has advantageous results when analyzing emotional regulation and cognitive function. However, there are not conclusive results when analyzing singular mindfulness exercises (Eisenbeck et al., 2018). Mindfulness is an alert mode of perceiving all mental contents such as sensations, perceptions, and cognitions (Walach et al., 2006). The definition of mindfulness is the capacity to openly attend, with awareness, to what is happening in one's present moment experience. Mindfulness teaches active awareness such as paying attention to one's internal experiences, including, body sensation, emotion, breath, and cognition (Cho et al., 2016). There are many benefits to practicing present-centered attention and openly accepting the experiences occurring within and around a person. These can include having a strengthened awareness, greater self-regulation, achieving greater openness and acceptance to different experiences, and the ability to develop new perspectives throughout the course of one's practice and everyday life (Mani et al., 2015). Humans tend to resort to being on autopilot and not taking the time to observe their surroundings and be attentive to themselves and their emotions. Mindfulness training forces the subconscious to awaken and causes the mind and body to slow down and be aware of the things around them. Mindfulness training serves a purpose in mental health promotion and has become increasingly popular in universities. Additionally, mindfulness is being thought of as a skill rather than just a passive mental health intervention. By actively bringing awareness to anxiety-related sensations, participants are able to reduce the emotional activity that is in part related to anxiety symptoms. Repeating active mindfulness practices assists the brain in forming stronger synaptic connections and rewires the conditioned responses that are normally enacted during a stressful situation or environment (Cho et al., 2016). This evidence demonstrates that continued practices are essential aspects to lead to a better conditioned response over time.

The underlying pathways in the brain that are impacted with utilizing mindfulness training are not completely understood, although, there is a theory that using mindfulness training techniques impacts health by changing one's reactions to stress. It is thought that mindfulness alters stress processing in the brain, which can then alter the peripheral stress response cascades. The peripheral pathways alteration decreases stress response cascades and there is an overall decrease in the risks for stress-related disease (Creswell & Lindsay, 2014). A study was done to evaluate mindfulness meditation on a group of college students and evaluate their stress perception, anxiety levels, and mindfulness skills. At the beginning of the study, about ⅓ of the students reported high levels of stress and anxiety, but after going through a six-week mindfulness training, none reported high stress or anxiety. From these results, it can be concluded that adopting a mindfulness practice for just once a week for six weeks will show reduced stress and anxiety in college students.

Breathing Regulation and Sleep Technology

Technology has become an easily accessible tool to help regulate and maintain a person's health through the use of watches to track heart rate, calories burned during exercise, sleep, and many other biometrics. Digital technologies have become easily accessible and have the potential to revolutionize the well-being and health of its users. Wrist worn tracking devices, such as the Apple Watch are arising more and more in healthcare (Falter et al., 2019). Some of these devices have different capabilities including the ability to measure and monitor various parameters such as energy expenditure, heart rate, steps, oxygen saturation, blood glucose, and potentially cardiac arrhythmias (Roomkham et al., 2019). These measurements are able to be provided as overall feedback on the user's smartphone (Falter et al., 2019). These vital parameters are of great interest to their users. People find technology safe and comfortable and turn to it to handle anxiety, stress and social isolation, as well as to block out negative emotions (Zhu et al., 2017).

A solution to an increased need of both convenience and usage of mindfulness due to the rising stress levels of everyday lives could be through the utilization of smartphone applications (Bostock et al., 2019). Apps tailored to treating mental health are becoming more and more popular in the current climate. Most of these mental health applications focus on interventions, rather than monitoring (Genaro Motti, 2018). Mental health apps could be the bridge to close the gap between the need for mental health services and the need for convenience. There has been initial evidence stating that technology being the standard of delivery for certain treatment protocols for a range of clinical disorders has demonstrated positive effects that are similar to those when using the conventional standard of care (Bostock et al., 2019). Another benefit to using apps is the uniformity of the services provided and delivered; participants can control when and where they participate in the intervention. Evidence is suggesting that technology is an adequate way to increase mindfulness exercises through convenience and therefore decrease levels of stress and anxiety overall (Bostock et al., 2019). These positive outcomes lead to an overall better quality of life and need to be explored and utilized more often in the future.

Sleep measurements are also a parameter that can be measured through the Apple Watch and other wearable tracking devices. Actigraphy is the most widely accepted clinical method for measuring sleep by using an accelerometer (Roomkham et al., 2019). A test was conducted to validate the Apple Watch tracking measurements in comparison with actigraphy, which also utilizes the user's movement to track sleep. The results showed that the Apple Watch had a high overall accuracy of 97% and sensitivity of 99% when compared to the results from actigraphy measured sleep (Roomkham et al., 2019). The adequate specificity when comparing wakefulness was 97% (Roomkham et al., 2019). Overall, these results are very promising and show that wrist worn tracking devices are useful and accurate in measuring different parameters. Overall, the Apple Watch overestimated total sleep time by about 6.31 minutes (Roomkham et al., 2019). It has been concluded that the Apple Watch is able to accurately measure different parameters such as sleep and heart rate and leaves a promising outlook for future advancements.

Mindfulness applications on smartphones have recently drawn attention. The mobile app "Calm" was studied to determine if it reduces stress on the university student population. A survey was distributed and filled out by each participant at the baseline (week 0), post intervention (week 8) and at a follow up time (week 12). This survey assessed the participant's perceived stress, self-compassion, mindfulness, health behaviors, and feasibility. These subjective measurements showed that there was a significant difference in the intervention group for perceived stress. There were no significant differences in the control group (Huberty et al., 2019). Overall, a majority of the students that participated in the Calm app intervention group concluded that this smartphone application was helpful in reducing stress and they would continue to use this application in the future (Huberty et al., 2019).

Mindfulness applications have recently become a feature on wrist worn tracking devices. Wrist worn tracking devices are more accessible, less obtrusive, and ensure interaction with the individual user (Genaro Motti, 2018). The potential shift of mindfulness techniques and practices to digital devices has a promising outlook to help increase awareness and mindfulness practices, but also do so in the most convenient way possible (Zhu et al., 2017). There is a need to increase our understanding in mental health promotion with wrist worn devices in order to fully investigate the potential opportunities and benefits of this technology (Genaro Motti, 2018). In doing so, future solutions utilizing technology for mental health purposes will be improved along with creating a standard way to collect a plethora of data (Genaro Motti, 2018). The Apple Watch is one of these tools and has a mindfulness feature that alerts its user to stop and do one minute of resonant breathing/mindfulness for a set number of times per day, depending on what the user decides to set the occurrence rate to. Participating in these mindfulness reminders is said to assist in helping the body slow down and taking time to observe the participants thoughts and feelings. One of the features that was consistently discovered on each high quality mindfulness applications was an emphasis on breathing (Mani et al., 2015). A majority of the high quality applications contained breathing timers and provided a reminder, features that also appear on the Apple Watch (Mani et al., 2015). There is potentially a correlation between the mindfulness exercises that the Apple Watch alerts its users to participate in and the user's sleep patterns. This correlation is able to be measured by wearing the Apple Watch on a daily basis as it is able to track all of these metrics. If utilized in a productive manner, wrist worn technologies have the potential to support its users when dealing with mental health issues in conjunction with standard practices of care (Genaro Motti, 2018). Technology is constantly evolving and advancing at an exponential level. That being said, the measurements able to be obtained through the

Apple Watch today will become more and more accurate and there is great potential to discover other health benefits employed by the Apple Watch in the near future.

Due to all the variables that lead to decreased levels of restful sleep in college students, the purpose of this study is to see if utilizing the Apple Watch as a mindfulness reminder will lead to more restful sleep overall. An increase in restful sleep will then increase cognitive function and the body's overall physiology. Increases in sleep quality and quantity can also play a vital role in reducing stress levels and anxiety in college students, a population that is very prone to concerns related to stress. Utilizing mindfulness through resonant or diaphragmic breathing can then help the body gain somatic control over breathing, as opposed to the body's normal autonomic control. All these factors together can show if the mindfulness exercises on the Apple Watch are beneficial to sleep and overall mental health.

Methods

Subjects

The study was conducted on the College of William & Mary campus. The study population consisted of students aged 18-22, representing a wide variety of social classes. This study was made up of volunteer participation, with both male and female participants, with 80% females and 20% males. Students were recruited through social media, word of mouth, text chains, or announcements by professors. This study had 36 individuals, all owning and using their personal Apple Watch.

Prior to the beginning of the recruitment for this study, this protocol was approved by the William and Mary Protection of Human Subjects Committee (PHSC) with the approved protocol ID PHSC-2021-11-03-15199-mbharr.

Procedures/Timeline

At the beginning of the study, each participant was given a consent form to sign detailing their volunteered participation in the study along with the option to stop the study at any time. Each participant was also given a self-report questionnaire (refer to Appendix A) asking a series of questions such as the last 4 digits of their William and Mary ID for confidentiality coding purposes along with demographic questions, such as which gender the participant identified with, to see the range of participants in this study. There was also a health history section on the questionnaire asking about each participant's exercise routine along with types of exercise they participate in.

Additionally, there was a section on the questionnaire requesting information on whether the participant already uses certain techniques that pertain to mindfulness and/or meditation and what those activities are. Lastly, there were a few questions asking each participant about their coping strategies when in periods of overwhelming stress or anxiety.

The participants were also required to set up mindfulness reminders if they had not already done so and download the Sleep++ application, which is one of the top recommended applications for sleep tracking. This study was conducted over a three-week period. During the first two weeks of the study, each participant was encouraged to do at least one to two minutes of mindfulness each day, either self-initiated or when prompted by the Apple Watch. Each participant was also required to sleep with their

Apple Watch on to track their restful, restless, and awake times and percentages each night through the Sleep++ app. These were the only parameters set for the first two weeks.

In the last week of the study, the participants were required to turn off their mindfulness and were asked to strictly not participate in any mindfulness reminders through the Apple Watch. Participants were still instructed to track their sleep using the Sleep++ application.

Restful sleep, according to the Sleep++ app is defined as your best sleep, when minimal movement was detected. Restless sleep was defined as asleep but with consistent movement, indicating restlessness. Awake is when the user is moving enough to no longer appear asleep.

At the conclusion of the three weeks, each participant gave their sleep data and mindfulness participation statistics. Analysis was then conducted using R for significance tests, excel for pivot tables, and Tableau for graphing techniques.

Through using data from the questionnaire, other parameters were also taken into account such as the number of days per week the participant exercised coupled with the amount of mindfulness minutes they did.

Exclusions

There were 36 participants at the beginning of the study but 11 were excluded as indicated below.

One participant was excluded due to not downloading the Sleep++ app, therefore, this participant's data was unusable as there was no standard measurement as compared to all using the Sleep++ app, thus there was no adequate way to assess this participant's sleep measurements. Eight participants stopped the study early or did not complete the three-week study entirely, thus rendering their results unfit to use. Two participants only participated in mindfulness for two days, each for one minute, and thus, did not have any comparable results from the first two weeks of mindfulness compared to the last week of without mindfulness practices.

Results

As shown in **Figure 1**, mindfulness reminders from the Apple Watch were shown to have a slightly significant difference (*p-value < 0.05*) in the amount of restful sleep of the participants. **Figure 1** demonstrates that the average restful value slightly decreased when participating in the mindfulness reminders, 95.17% when not participating in mindfulness as compared with 94.06% when participating in one minute of mindfulness per day. When a linear regression test was run to assess mindfulness minutes in relation to restful sleep, the coefficient for variable mindfulness minutes was -0.5774, meaning that an increase in mindfulness minutes decreases the amount of restful sleep. Based on the regression, there was significance in mindfulness minutes in that it negatively impacts restful sleep. Mindfulness minutes are important in predicting restful sleep, the p-value being 0.0411. Time asleep was also a significant value in determining impact on restful sleep, as the time asleep correlated with restfulness had a p-value of 2e-16. The adjusted R squared value was 0.9951, showing that this data was able to be explained adequately by the regression model that was run that correlated time asleep, restful minutes, and restless minutes all in comparison with mindfulness minutes.

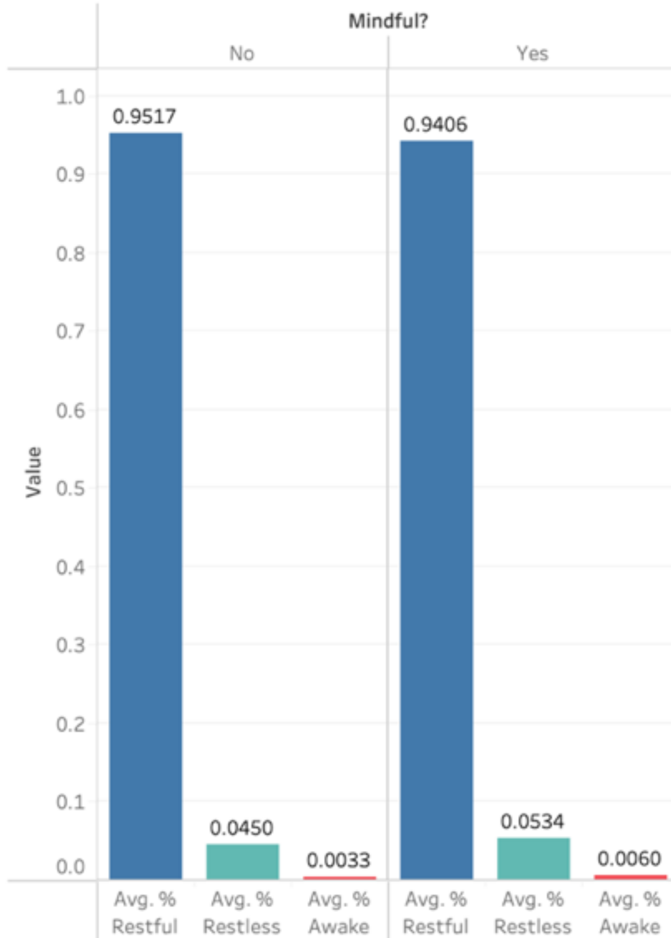

Figure 1 Average restful, restless and awake values compared to participating in mindfulness for at least one minute per day. Results show that not participating in mindfulness slightly increased the amount of restful sleep, in turn decreasing the restless and awake time periods throughout a night's sleep. The sample size was 25. Note*: p-value < 0.05.*

Another factor that was evaluated was the amount of exercise, in days per week, compared to average restfulness. In **Figure 2**, there is a positive linear trend showing that the more days per week that the participants exercised, the more restful their sleep was on average. A participant that did not exercise had an average restfulness of about 92.3% and for a participant that did about 5 to 7 days of exercise/activity during the week had an average restfulness of about 95.3%. The p-value for exercising 5 to 7 days a week was significant at 0.0313 and the p-value for exercising 3 to 4 days a week was almost significant at 0.0672. This shows that exercising around 5 to 7 days a week can significantly affect the amount of restful sleep of the participants.

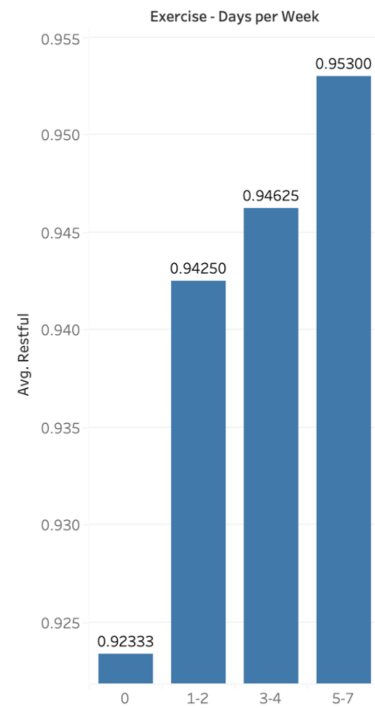

Figure 2 Average restful sleep when comparing to the amount of days per week each participant exercises (n = 25).

Figure 3 demonstrates that, on average, males participated in more mindfulness than females did. Note: gender determination was a question asked before the start of the study on the questionnaire and stated, "which gender do you identify with?" Males had a slightly lower average restfulness, by about 0.2%. Females had an average restfulness of 94.6% compared to males average restfulness of 94.4%, as shown in **Figure 4**. On average, females participated in about 11.7 minutes of mindfulness in total during the allotted study time, whereas males participated in about 12.8 minutes of mindfulness total throughout the course of the study. **Figure 3** in conjunction with **Figure 4** suggest that, in this study utilizing the Apple Watch as the source of the mindfulness practices, mindfulness is not a positive contributor to restful sleep. There is no statistical significance shown based on the gender of the participant correlated with their restful sleep, thus the correlation between the male and female participants and their restfulness and mindfulness minutes is null.

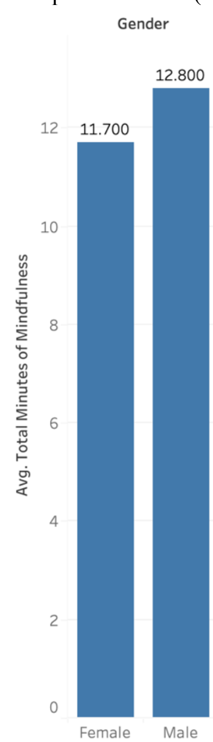

Figure 3 Average minutes of mindfulness that each gender participated in (n = 25).

As shown in **Figure 5**, participants varied in the number of days they exercised per week as well as the total minutes of mindfulness. There was a clear positive trend, as shown in **Figure 2,** comparing participants' restful sleep to days per week of exercise. It is apparent that mindfulness minutes on average are not a good predictor of the average restful sleep. In **Figure 2,** the average restful sleep showed a clear upwards trend when directly correlated with the number of days per week the participant engages in exercise. In **Figure 5**, the amount of mindfulness minutes varied widely across each range of days of exercise, yet the restfulness trend was very clearly upwardly correlated**.** Note: There is no significance shown (p-value > 0.05) between gender days of exercise affecting the amount of restful sleep each participant obtained.

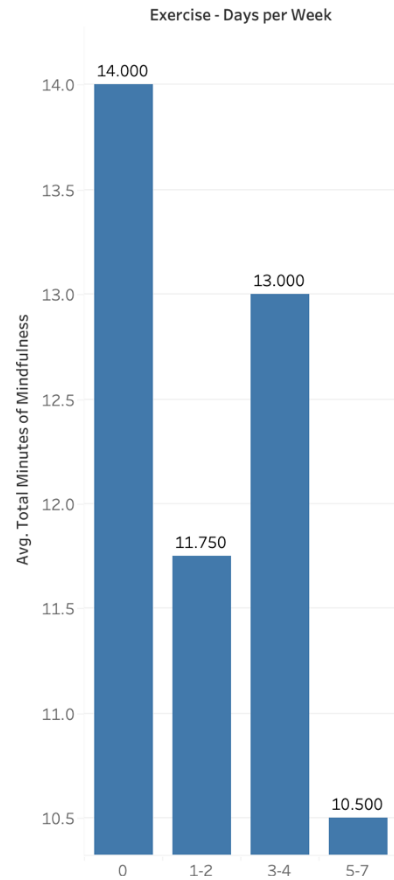

Figure 5 Exercise in days per week as compared to the average total minutes of mindfulness each group participated in (n = 25).

Discussion

This study involved testing the hypothesis of the potential for an easier and more convenient way to increase sleep quality and quantity through the use of commercially available wearable technology, in this case, the Apple Watch. Increased levels of stress, a common problem in the university student population, has been shown to have detrimental effects on the use of positive health behaviors (Nagy et al., 2020). Technology has become an easily accessible tool to help monitor different biometrics (Falter et al., 2019). Resonant breathing, or breathing 6 to 7 breaths per minute, has shown to improve cardiovascular functionality and is the technique used for the mindfulness feature on the Apple Watch (Nuckowska et al., 2019). It was predicted that even short periods of mindfulness (one to two minutes per day) while utilizing technology would have a significant effect on sleep quality overall. However, the results of this study did not agree with these predictions but instead indicated that around one minute of mindfulness per day showed to have a slightly detrimental effect on sleep quality overall. As shown in **Figure 1** above, restful sleep decreased by about 1% overall when the participant practiced mindfulness. This result had a p-value of 0.0411 and was therefore significant. This result could be due to many confounding factors such as the timing of the study (i.e. further into the semester having more baseline stress and anxiety due to midterms), the different workouts that each subject actively participates in on a daily or weekly basis, and increased light pollution which have been shown to have a detrimental effect (Medic et al., 2017). With more studying and note taking being done on some sort of technology with a screen, college students are prone to exposing themselves to excessive nighttime light pollution and underexposing themselves to daytime sunlight (Medic et al., 2017). Unfortunately, these factors are unable to be controlled as this study was conducted during the semester during which students are utilizing ample amounts of technology on a daily basis. Each student's screen time and light pollution varies but is unable to be adjusted due to the primary use of technology in the classroom. When comparing time asleep and mindfulness minutes, it was demonstrated that time asleep is a better predictor for the variation in restful versus restless sleep. It was shown that the more time the participant is asleep, the more restful sleep they will have overall. When the linear regression was run, the significance test showed a very high and significant correlation in this data.

When the body is in a stressed state, there is an increase in breathing, thus causing the breathing to be more shallow and more tense (Zhu et al., 2017). The objective of the mindfulness reminders on the Apple Watch are to help control this state and assist to help the body to a state of calm and conscious deep breathing (Zhu et al., 2017). Participating in calm and conscious breathing will then decrease stress and anxiety and therefore aid in better sleep quality overall (Zhu et al., 2017). The Apple Watch encourages its users to participate in mindful breathing and help the body transition from autonomic control to somatic control. The Apple Watch encourages its users to participate in this resonant breathing but was found to only have a slightly significant correlation to adequate sleep quality. That being said, this correlation was slightly negative, suggesting that only doing one to two minutes of mindfulness activities throughout the day has a detrimental effect on sleep quality. A study linking mindfulness practice quality with practice time suggests that greater practice time was correlated with better practice quality overall (Goldberg et al., 2020). Further, the better the quality of the practice was overall, the better the self-reported mindfulness and psychological symptoms were reported (Goldberg et al., 2020).

Mindfulness Based Stress Reduction (MBSR) is comprised of a 2.5 to 3 hour instructor lead group session each week as well as a 45 to 60 minute mindfulness practice each day for 8 weeks (Klatt et al., 2009). Due to the MBSR program's time commitment, it is unlikely in the university student population that this would be sustainable. This study utilizes a non-verbally guided feature on a wrist worn device, thus, differentiating it from MBSR as MBSR utilizes mindfulness coaches either through a recorded setting or in person (Klatt et al., 2009).

There have not been studies utilizing the Apple Watch to determine a baseline amount of time a participant should practice mindfulness per day in order to obtain significantly better sleep quality and quantity. Due to there not being any studies testing for the baseline amount of mindfulness minutes used per day, each participant was encouraged to participate in however many mindfulness minutes they see fit. Most participants participated, on average, in about one minute of mindfulness per day. These results showed that participating in around one minute of mindfulness per day decreased restful sleep, as discussed above. Controlling for a higher average threshold of minutes of mindfulness per day could potentially lead to a positive correlation with sleep quality. The results of another study suggested that higher levels of dispositional mindfulness were correlated with better sleep patterns due to the participant feeling as though they have better control over their own health (Imel et al., 2018).

The previously discussed studies deal with subjective measurements through the use of questionnaires before, during, and after the time frame of the study (Huberty et al., 2019). The present study is only concerned with objective measurements. There are times where the subjective reporting of one's sleep quality does not match the objective measurements (Weathers et al., 2020). While still a reliable study, as the measurements entail the participants' personal assessment of their stress level and other physiological factors, a participants' subjective results could indeed differ from objective results. Therefore, it could have been the case where even in the previous study, although contradictory with the present findings, could have had the same objective results, depending on the mindfulness exercises that were implemented. Overall, the participants might not have participated in enough mindfulness reminders to make a significant difference in their sleep results. A future study could possibly set a higher threshold for minutes of mindfulness per day or a longer time frame for conducting the study in order to achieve more accurate results.

The amount of exercise a participant engages in on an everyday basis was a good predictor for the sleep quality. For example, on average, more weekly exercise and physical activity leads to greater restful sleep overall. Exercise has become a growing field of research to use as a non-pharmacological approach to increase sleep quality and quantity overall (Kline, 2014). Based on the significant results found in this study, these would further suggest the positive correlation between exercise and sleep quality. A study concluded that even a single time exercising can increase slow wave sleep, or deeper sleep (Uchida et al., 2012). Note: Slow wave sleep, i.e. stage 3 of sleep, is a deeper form of sleep and is followed by REM sleep, thus, increasing restful sleep. The current findings further demonstrate that exercise is significantly able to increase restful sleep. A future study could control for time of day that the participants exercise to control for another possible confounding variable.

There are many confounding variables that need to be accounted for in this study including environmental factors and social pressures (Medic et al., 2017). There are genetic, psychologic, and biological factors that all contribute to the variability in sleep in humans. College students are constantly on the move and not able to maintain a consistent sleep schedule. These environmental factors that delay bedtimes or keep students up during the night are factors that unfortunately are unable to always be accounted for or solved. Future studies could encourage students to sleep within a 12-hour time frame to control for the body's natural circadian rhythm timings and assess if the timing of sleep affects sleep quality in a significant manner. Students also vary widely in the amount of caffeine consumed from person to person but also differ on an everyday basis. Caffeine is a stimulant and will also result in inadequate amounts or quality of sleep (Medic et al., 2017). A future study could standardize the amount of caffeine intake in participants which could control for the inadequate amounts of sleep quality due to increased stimulation. Students are constantly looking at screens and are exposed to a lot of nighttime light pollution, another factor that has been proven to cause lower qualities of sleep (Medic et al., 2017). Light pollution control is unfortunately infeasible to control for as a university student's life revolves around the use of different technologies daily through the utilization of a smartphone, using laptops or tablets for studying or lecture purposes, or a plethora of other ways screens are used daily. As mentioned earlier, due to all these factors that lead to decreased amounts of restful or REM sleep, there is decreased cognitive or physiological functions, which then heighten problems for the future.

An aspect of this study to consider is, in the literature review, most of the studies that found positive correlations between mindfulness and other variables did so in a subjective manner. As talked about, the subjective reporting of sleep quality does not always match the objective measurements (Weathers et al., 2020). Another aspect to consider is the subjective bias. If the participant believes that mindfulness interventions will positively affect their sleep or their quality of life, when using subjective measurements, the participant could hold a bias towards greater improvement than was the actual case when using objective measurements. In the future, a study could ask participants to fill out a post-study questionnaire, judging how they felt their stress and anxiety levels were and compare those results to tactical biometrics.

Human studies require a lot more subjects than are expected to be included in the final results. This study had recruited 36 but was only able to utilize the results of 25 subjects. That being said, a future study would account for more outliers or exclusions when recruiting as well as create a better timeline to recruit more participants. A future study could also utilize incentives as a way to motivate participants to both participate in the study and follow the protocols set out for them. Future studies would also need to account for at least one or more of the confounding variables in order to ensure the results of this study are not only statistically significant but also meaningful.

Conclusion

Overall, this study suggests that at this point, the convenient use of the Apple Watch for mindfulness purposes is not the most efficient use of technology within a 3-week span. As mentioned above, utilizing smartphone watches could prove to be a beneficial way to standardize care and create a sufficient and convenient way to prioritize mental health and increase quality of life. Different aspects of the Apple Watch have the potential to be beneficial over the long term, especially when engaging in more mindfulness reminders overall. A future study could be conducted that requires at least 10 minutes of mindfulness throughout the day in a more regimented fashion and analyzing if those results correlate with sleep in a more significant way.

Some future ideas for this study could be testing for a longer period of time, controlling the specific time of day that the participants complete the mindfulness exercises, recruiting more subjects, having a control group, grouping participants based on the amount of exercise and type of exercise they do per week, or controlling these exercise factors in order to create a more standardized measurement of restfulness. In a future study, caffeine consumption should be controlled for in order to limit this other confounding variable. Light exposure and each university student's sleep schedule were things not controlled for in this study. Due to the day to day lives of college students and the increased use of technology in the classroom, nighttime light pollution is almost inescapable. A study that would control other variables like light pollution exposure or standardizing the times the participants sleep and wake over potentially a 12 hour time frame during nighttime hours could also create a more uniform study overall and therefore, differentiate the results from the current study.

Mindfulness has been shown to have a beneficial effect on sleep quality overall when the participants do mindfulness training over a long period of time based on previous studies. This study was done over a 3-week time period but the results could have shown a different outcome if the study was done over a longer period of time or if the participants had a higher baseline number of mindfulness minutes required to participate in each day. Participants were encouraged to participate in mindfulness, but there were no specific parameters set for time of day. There could be a potential correlation in the time of day that the participant does the mindfulness exercise in accordance with their sleep schedule, which is another aspect that could be evaluated in a future study.

Exercise was also not a controlled factor during this study. Each participant exercised a different amount throughout the course of the week and participated in a different type of exercise throughout the week. There was a positive correlation found between restful sleep and the amount of exercise participated in per week. Since exercise was not a controlled variable during the present study, a future study could control for exercise to limit this confounding variable. Increasing the number of subjects participating in the study could also assist in studying the difference in the effects of mindfulness training on sleep quality and quantity in high fit versus low fit individuals.

Lastly, each stage of sleep is classified by brain wave activity and could be a better indicator of sleep quality compared to analyzing body movements. At the present, there is no wrist worn technology that can measure brainwaves. As a future study, potentially looking at the brainwave activity to get a more accurate reading on the specific stage of sleep for each participant could spark some interesting findings.

Appendix A

Self-Report Questionnaire

Demographic Questions:

1. What are the last 4 digits of your W&M ID?
2. What is your age?
3. What gender do you identify with?
4. What is your predicted graduation year?

Health History Questionnaire

1. Do you exercise throughout the course of a normal semester?
    a. If yes, how many times a week?
    b. How many hours?
    c. What kind of exercise do you participate in?
2. Do you play any sports that require you to not wear your Apple Watch?
    a. If yes, how many times a week?
    b. How many hours?
    c. Which sport/sports?
3. Do you take any medications?
4. Do you participate specifically in mindfulness or meditation?
5. Do you ever allow yourself breaks throughout the week/month?
6. Are there certain times that you feel more overwhelmed or stressed compared to other times?
    a. For what reasons?
    b. How do you cope?
7. What other activities (i.e. job, volunteering, etc.) are you currently participating in?
    a. What is your schedule for those activities?

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